SLOW SAND FILTRATION

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World Health Organization, Geneva

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CONTENTS

Preface

In recent years there has been a tendency to assume that slow sand filtration is an old-fashioned method of water treatment that has been completely superseded by rapid-gravity and other high-rate filtration techniques.

This idea is definitely mistaken. Under suitable circumstances, slow sand filtration may be not only the cheapest and simplest but also the most efficient method of water treatment. Its advantages have been proved in practice over a long period, and it is still the chosen method of water purification in certain highly industrialized cities as well as in rural areas and small communities. It has the great advantage over other methods that it makes better use of the local skills and materials available in developing countries, and it is far more efficient than rapid filtration in removing bacterial contamination.

Because of the evidence that water treatment designers tend to neglect consideration of slow sand filters when planning new works, the World Health Organization commissioned Professor L. Huisman, an internationally known specialist in water treatment, to visit and report on installations using slow sand filtration in various parts of Europe and to compare costs and performance, particularly with regard to the quality of the treated water. From his original study, Professor Huisman, in collaboration with Mr W. E. Wood, formerly Chief, Community Water Supply, WHO, developed the present book, which describes the construction and operation of modern slow sand filters, the latest developments in operating techniques, the theory of biological filtration, and the application of the principle of slow sand filtration to the artificial recharging of groundwater sources—a technique practised extensively in the Netherlands.

It is hoped that the book will encourage the greater use of the excellent and reliable method of slow sand filtration, especially in developing countries.

1. Introduction

The object of this volume is to discuss the various aspects of one particular form of water treatment—the "biological filtration" or "slow sand filtration" process. This system of water purification has been in continuous use since the beginning of the nineteenth century, and has proved effective under widely differing circumstances. It is simple, inexpensive, and reliable and is still the chosen method of purifying water supplies for some of the major cities of the world.

A myth has grown up that this process is old-fashioned and therefore inefficient, that new techniques have rendered it obsolete, and that because it is simpler than many more recent innovations it is necessarily inferior to them.

None of these objections to biological filtration is warranted. In many circumstances it is still the most appropriate choice when treatment methods are being selected, and the designer who automatically turns to other methods is often acting in ignorance of the potentialities of the technique.

It is perhaps paradoxical that this water treatment process, the oldest of them all, is one of the least understood and that less scientific research has been carried out into its theoretical and practical application than into other more recent but less effective methods. It is hoped that this volume will help to redress the balance. No startling new discoveries are reported; rather, the book gathers together the results of practical experience gained in many countries under diverse conditions and summarizes the theoretical work carried out in many institutions on different aspects of the process. It does not claim that the processes described are necessarily applicable everywhere and under all conditions; indeed, no single panacea has yet been found, or is likely to be found, that will solve every water treatment problem. It is hoped, however, that it will enable those responsible for deciding on treatment methods for new supplies to judge whether safety, efficiency, and economy may be more readily attainable through the use of slow sand filters than through the use of any other comparable method in the prevailing conditions.

Before proceeding to describe the details of the process, we shall first consider the criteria upon which such judgements depend.

Water quality criteria

Modern technology provides a choice of treatment methods that can produce virtually any desired quality of water from any given source, the limiting factor being economic rather than technical. Where cost is no constraint, it is possible to obtain water of an extremely high degree of purity from such unlikely raw materials as seawater or sewage effluent by a variety of methods such as distillation, electrodialysis, or reverse osmosis. Compared to the cost of producing drinking-water from relatively unpolluted ground or surface water sources, such processes are very expensive and are outside the scope of the present volume, which will be confined to a discussion of the so-called "conventional" methods of treatment.

By the selection and combination of different stages of treatment and by the judicious choice of source, it is possible to achieve varying degrees of water quality at varying capital and running costs. Those responsible for planning new supplies must therefore decide first of all what they want to achieve in this direction.

It is probably easiest to define the minimum quality that should be permitted in any water supply destined for drinking and domestic purposes. This minimum standard water is often referred to as "safe" water because it contains nothing that can harm the consumer, even when ingested over prolonged periods. To achieve this condition, parasites and pathogenic organisms must be reduced or inactivated to the point where they do not constitute a hazard to the consumer, and toxic and radioactive substances must not be present in excess of the maximum permissible levels that research and experience have shown to be safe. Guidance on these matters may be found in the *International Standards for Drinking-Water.*[1]

A safe water is one that cannot harm the consumer when drunk under normal conditions. This does not necessarily mean that it is pleasant to drink or to use for domestic purposes. It may be coloured, excessively hard, have an unpleasant odour, possess a bitter or salt taste, contain iron or manganese salts that stain clothes washed in it, or corrode pipes and metal fittings with which it comes into contact. In some cases it may be sufficiently unpalatable to drive consumers to other, less safe, sources. Water supplied to a community should therefore be not only completely safe but agreeable to use; such a supply may be termed "acceptable" or "potable".

The provision of more social amenities and greater economic prosperity of a community are usually followed by a call for an increasing standard of water quality, for which the community is prepared to pay. Occasional harmless discoloration due to seasonal turbidity of the source, which may

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[1] World Health Organization (1971) *International standards for drinking-water*, 3rd ed., Geneva.

be acceptable in a remote village, will not be tolerated in the modern city. Prosperous communities demand a "good" water—one that is safe and has consistently good physical properties, with perhaps other refinements such as carefully controlled pH and hardness, the addition of fluorides to combat dental decay, an absence of chlorine smell, a "live" taste associated with the correct degree of oxygenation, and so on. It is unlikely that all these demands will be made in the initial stages, but the planner, while attempting to meet the customary need for economy, must make provision for the later addition of refinements, which experience has shown are eventually demanded by consumers.

Choice of raw water sources

It is often stated that when alternative sources of water are available for use as a public supply the overriding criterion for selection should be the quality of the raw water. Although there is some foundation for this assertion, it is not invariably true; reliability may be more important, since technically it is often more feasible to improve the quality than to increase the quantity of a supply. In a natural desire to supply the safest and best quality water possible, the planner may underestimate the importance of ensuring that the source is of sufficient size to satisfy future demand. Just as improved quality is called for with improved social and economic conditions, so does the amount of water required increase. This increase is due to two separate pressures—population growth and greater personal requirements of individual members of the population. It is worth noting that in several cities suffering from outbreaks of cholera it was established that the quality of the water delivered by the public supply was satisfactory but that the quantity was insufficient, so that people were forced to drink from other, unsafe, sources.

With this proviso, it is undoubtedly good practice whenever a choice exists between two sources of adequate capacity to select the one that is potentially least dangerous. The word "potentially" is stressed; the present excellent quality of the mountain stream is no guarantee of its future quality, and treatment proposals must always assume that at some time it will become contaminated with human excreta and that the individual from whom this contamination originates will be suffering from (or be a carrier of) an infection capable of being transmitted by water.

This potential hazard must always be attributed to surface supplies, however rigidly it is possible to control the catchment area from human access. Seagulls, for instance, can transmit infection from a sewage disposal works or sewer outfall to any open body of water on which they subsequently alight. Thus, when an adequate source of groundwater exists it will almost always be worthy of consideration as a preferable alternative.

Exceptions occur, of course, as with groundwater held in karstic limestone that has fissures through which pollution can rapidly travel from the surface to the groundwater. Again, subsurface supplies may be so heavily impregnated with minerals that they constitute a hazard from chemical toxicity. In general, however, it is true to say that groundwater needs minimal or no treatment while surface water must always be assumed to contain pathogens that have to be removed or inactivated.

It is sometimes claimed that surface water can be so effectively treated that the advantages of groundwater sources can be ignored, but there is always an implicit hazard (however remote) when the quality of the delivered water depends on the regular supply of chemicals or on freedom from human error or mechanical breakdown.

Certainly for smaller supplies, and for those where supervision and skilled operation are less than desired, there is much to be said for choosing a safer underground source (provided that its reliability has been established) even if its use involves some additional capital and recurrent cost. Such extra expenditure is, in any case, frequently counterbalanced in whole or in part by savings in the cost of treatment.

Choice of treatment processes

In its natural state, during its passage through the hydrological cycle, water is constantly changing in chemical and bacteriological composition. Polluting and purifying processes are continually at work. At the moment of evaporation from the ocean's surface it is virtually a pure compound of hydrogen and oxygen; when it reaches the point of condensation it is mixed with carbon dioxide and other gases; during its fall to earth it collects dust particles and dissolves further gases, both those naturally occurring and those present as pollutants in the air. On reaching the ground and during its passage above or within the ground it not only dissolves minerals from the rocks with which it comes into contact but also acquires a load of suspended solids (many of organic origin) and an infinite variety of living matter, ranging from microorganisms through a number of animal and vegetable species to large and complex aquatic life forms, such as fish and water weeds. At the same time it is being acted upon by sunlight, aeration, biological oxidation, settlement, chemical reactions, and the action of predators in the ascending food chain, all of which tend to convert those organisms that might be hazardous to humans into harmless and even beneficial forms.

Man, extracting water at any stage of this cycle, makes use of these natural processes of purification and creates conditions that will enable them to be speeded up in time and compressed in space. However complex or sophisticated modern processes may be, each has (with one exception)